1. Name of Experiment/Project/Collaboration: **Advanced Scintillation Detector Concept (ASDC) – temporary name**

2. Physics Goals
    a. Primary: **Long baseline neutrino physics (mass hierarchy, CP violation), neutrinoless double beta decay (DBD), solar neutrinos, proton decay**
    b. Secondary **Sterile neutrinos, supernova neutrinos, DSNB, geo-neutrinos**
3. Expected location of the experiment/project: **Homestake**
4. Neutrino source: **LBNF beam, the Sun, supernovae**, **Earth**
5. Primary detector technology: **Water-based liquid scintillator (WbLS)**
6. Short description of the detector: **Large-scale (100kt) monolithic detector with a WbLS target surrounded by high-efficiency, ultra-fast photon detectors with high coverage.**
7. List key publications and/or archive entries describing the project/experiment.
    a. arXiv:1409.5864 **"Advanced Scintillator Detector Concept: A Concept Paper on the Physics Potential of Water-Based Liquid Scintillator"**
    b. **M. Yeh et al., "A New Water-based Liquid Scintillator and Potential Applications", Nucl. Inst. & Meth. A660 51 (2011)**

8. Collaboration
    a. Institution list

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Institute of Physics & EC PRISMA, Johannes Gutenberg-University Mainz, 55128 Mainz, Germany

a. Number of present collaborators **60**
b. Number of collaborators needed. **500**

9. R&D
    a. List the topics that will be investigated and that have been completed

i) WbLS cocktail development: light yield, timing, attenuation, isotope loading, purification, recirculation, compatibility, long-term stability
ii) Photon detection development: efficiency, speed, read out
iii) Technical demonstrations: separation of Cherenkov and scintillation light components and event reconstruction using fast timing

    b. Which of these are crucial to the experiment.

We need to demonstrate the ability to tune the WbLS cocktail in terms of scintillation timing, light yield, and attenuation length, in order to optimize for the physics goals.

Long attenuation length in the Cherenkov spectrum is important to retain sufficiently high detection of Cherenkov photons.

The low energy program, and in particular a DBD measurement requires sufficiently high light yield and collection efficiency, with low absorption, in order to achieve at least 160 pe/MeV light detection.

DBD requires successful loading of 130Te at high loadings, without significant detrimental effect on the WbLS optical properties. (Already demonstrated at 0.5% for SNO+).

    c. Time line

FY'15-16: bench-top scale R&D (BNL, Chicago, UCLA, MIT, LBNL, UC Berkeley, UC Irvine, UC Davis, UPenn)

FY'16: ton-scale demonstration at BNL

FY'18 (ish): potential for kt-scale demonstration in phase II of WATCHMAN detector

    d. Benefit to future projects

The ASDC has a broad program of compelling science, with the unique ability to combine conventional neutrino physics with rare-event searches in a single detector. Critically, the ASDC has the flexibility to adapt to new directions as the field evolves: the WbLS target is a powerful target due to its flexibility, allowing it to be refined for particular physics goals.

10. Primary physics goal expected results/sensitivity:

LISTED BY PHYSICS GOAL, BELOW

    a. For exclusion limit (such as sterile neutrino search), show 3-sigma and 5-sigma limits
    b. For discovery potential (such as the Mass Hierarchy), show 3-sigma and 5-sigma.

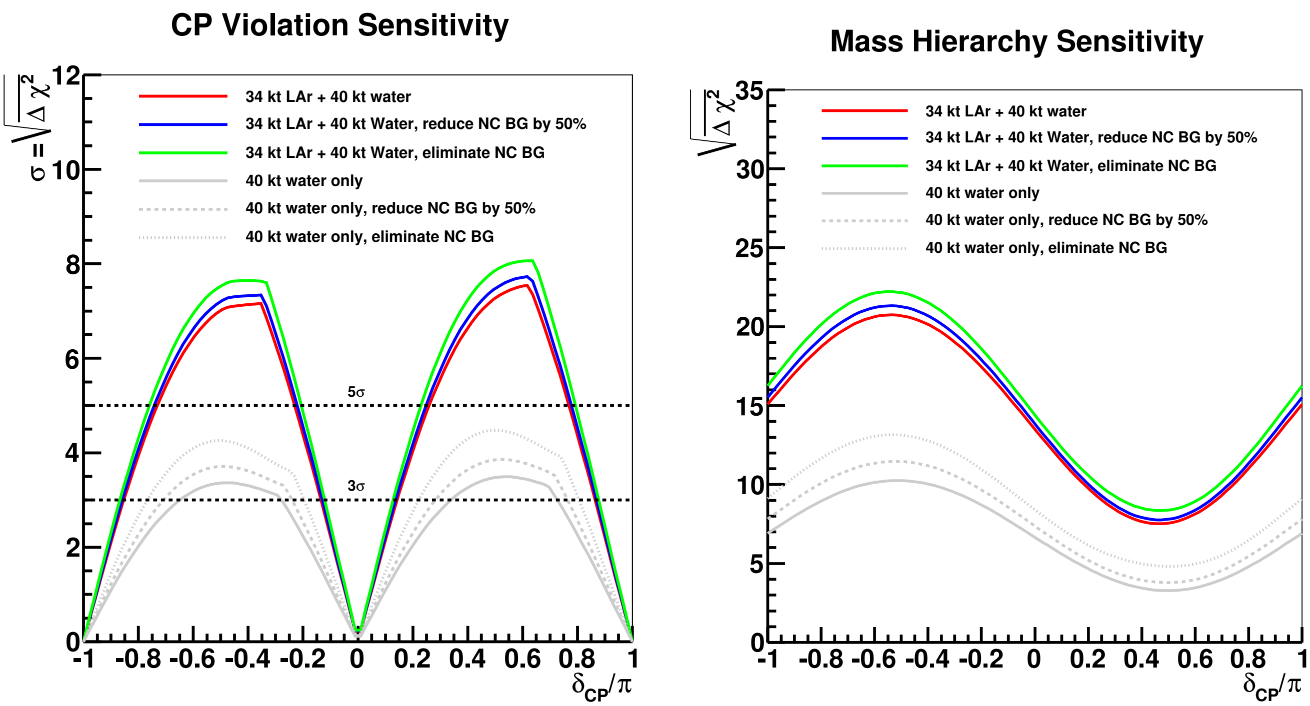
c. For sensitivity plots, show 3-sigma and 5-sigma sensitivities
(note that for neutrino-less double beta decay experiments that have previously been asked for 90% CL and 5 sigma limits these are OK)

d. List the sources of systematic uncertainties included in the above, their magnitudes and the basis for these estimates.

e. List other experiments that have similar physics goals

f. Synergies with other experiments.

i) Long-baseline neutrinos



Significance of sensitivity to CP violation (left) and neutrino mass hierarchy (right), as a function of the true value of delta_CP, for a 34-kT LAr TPC in combination with an additional 40-kT WCD when neutral current background is reduced by 50% (blue) or removed (green) from the WCD event sample. Gray curves show the sensitivity of the 40-kT WCD detector alone. All detector masses are fiducial and all sensitivities are calculated at a baseline of 1300 km in the LBNF nominal beam. The normal hierarchy is assumed, and oscillation parameters and uncertainties are taken from a recent global fit. The absolute sensitivity is dependent on these parameters, in particular the choice of theta_23, but the relative comparison is unaffected. Note: these curves assume no improvement in reconstruction from Super-K.

a-c. See figure for discovery potential for neutrino mass hierarchy and CP violation. A 40-kton fiducial ASDC alone could achieve 4.8 sigma on the MH across the entire range of delta_CP.

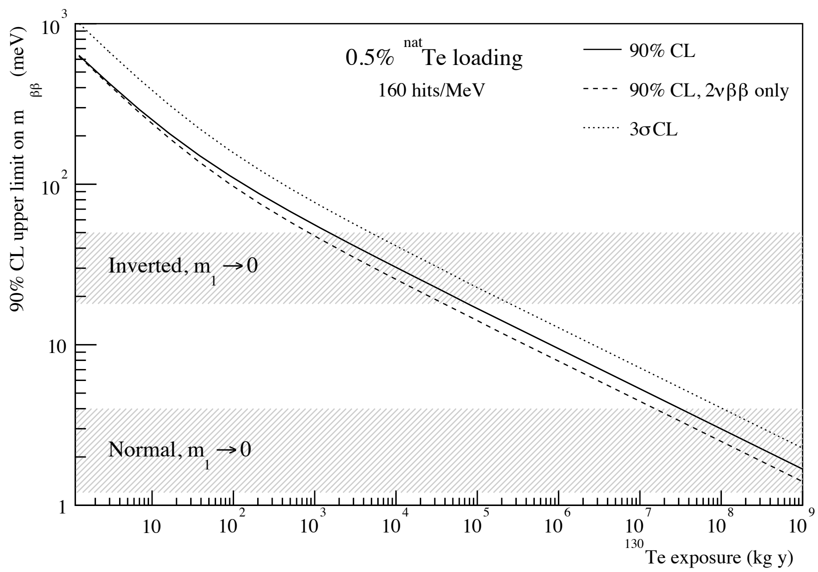
d. Long-baseline studies use signal and background normalization uncertainties to approximate the systematics. These uncertainties are treated as 100% uncorrelated among samples and so represent residual uncertainties for each sample. The values are 5% signal

and 10% background on nu_mu/anu_mu with 1% signal and 5% background residual on nu_e/anu_e. This is normalization only; energy scale uncertainties are not included yet. Uncertainties are treated as 100% uncorrelated between LAr and WCD. Uncertainties on the oscillation parameters are taken from the Capozzi global fit to neutrino data and are also included as nuisance parameters.

e. ELBNF, plus other MH experiments – Pingu, JUNO, HyperK, NOvA, T2K

f. Complementary program to the proposed LAr detector of ELBNF e.g. independent check of systematic uncertainties such as interactions of neutrinos on LAr at GeV energies.

ii) Neutrinoless double beta decay



Sensitivity as a function of 130Te exposure, for a 90% CL limit on effective Majorana neutrino mass and a 3 sigma discovery of 0-neutrino DBD for a 0.5% natural Te loading in a 50kt WbLS-filled ASDC (50t of 130Te), assuming a light yield of 160 pe/MeV. Also shown is the limit achievable if all backgrounds but 2-neutrino DBD were removed.

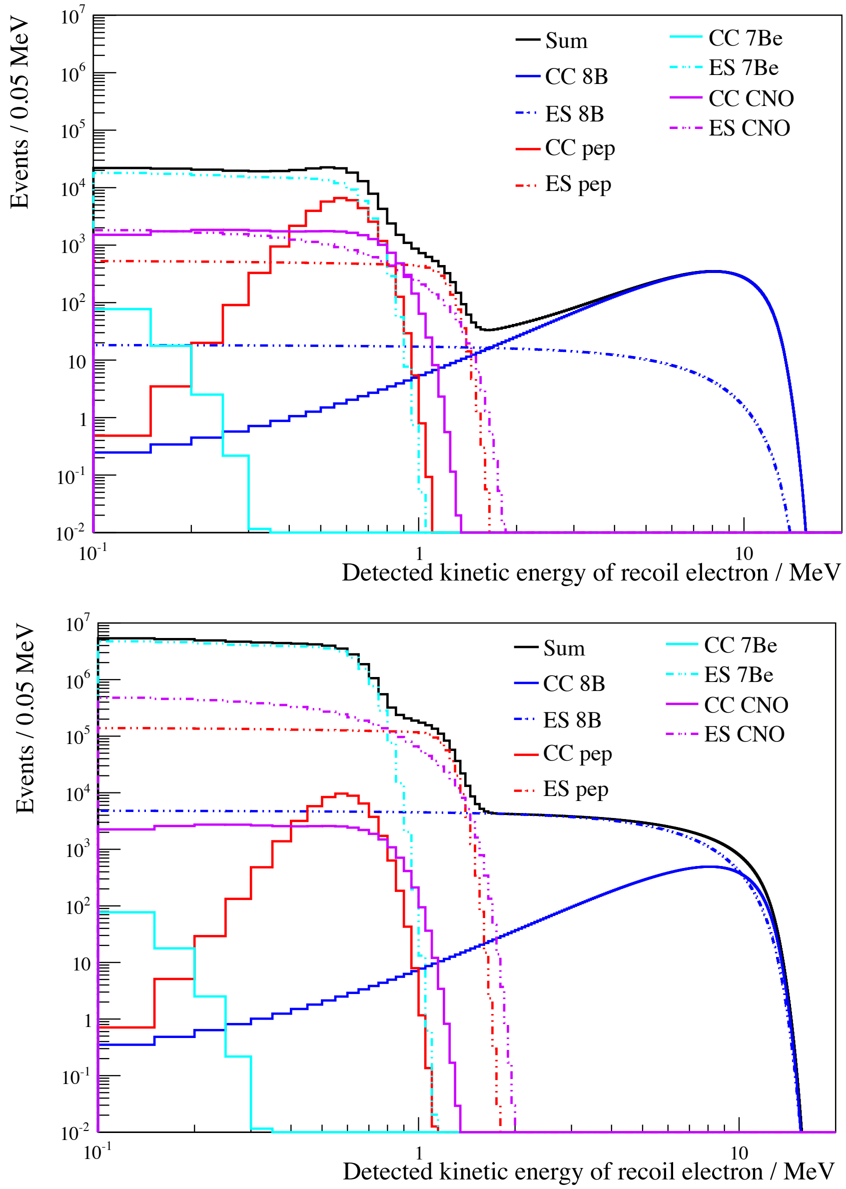
a-c. See figure for discovery potential and sensitivity to 0-neutrino DBD.

d. An energy resolution based on 160pe/MeV (5% at the end-point) is assumed.

e. Next-generation DBD experiments: CUORE-IHE, Majorana, nEXO, SNO+, KamLAND-Zen, Super-Nemo

f. Discovery of 0-neutrino DBD will likely require observation on multiple isotopes.

iii) Solar neutrinos

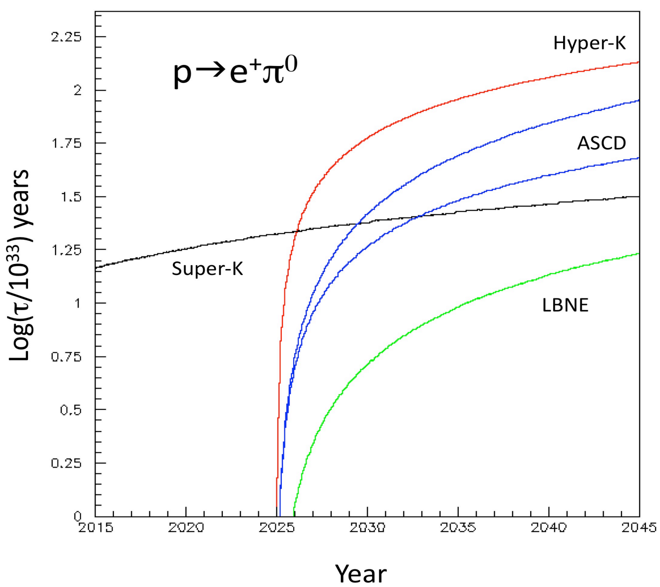


(Top) Predicted solar neutrino spectra in a 30-kT WbLS-filled ASDC detector loaded with 1% 7Li by mass. Light yield of 100 p.e./MeV assumed. (Bottom) The same spectra with a cut on cos(theta_sun)=0.4, reducing the ES component to illustrate the power of CC detection.

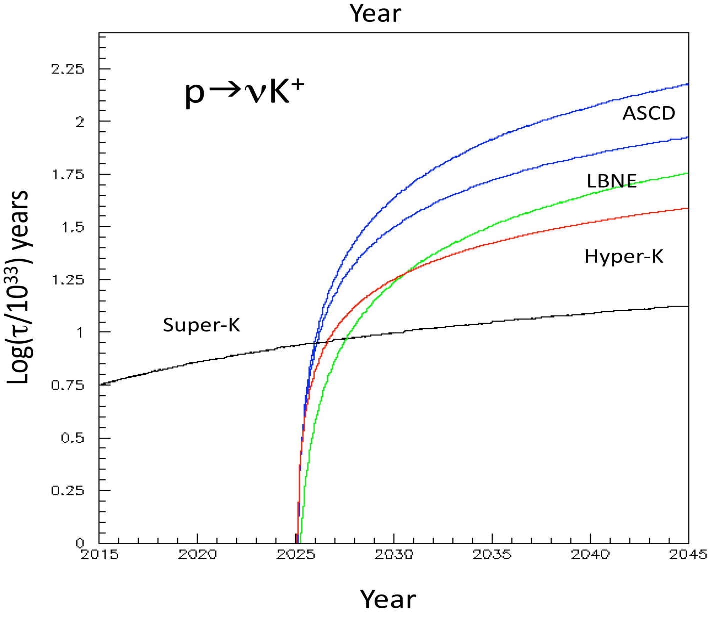
a-c. See figure for predicted solar neutrino spectra. We predict 5 sigma sensitivity to searching for non-standard physics in the shape of the 8B neutrino spectrum. Sensitivity to pep neutrinos would be percent-level, and to CNO would be on the order of a few percent.
d. An energy resolution based on 100pe/MeV is assumed.
e. Borexino, LENS

f. ASDC can target the higher energy end of low-energy solar neutrinos (0.5-5MeV) with unique precision. It was highly complementary to an experiment such as LENS or a liquid noble gas detector such as CLEAN, which could make a %-level measurement of the pp flux.

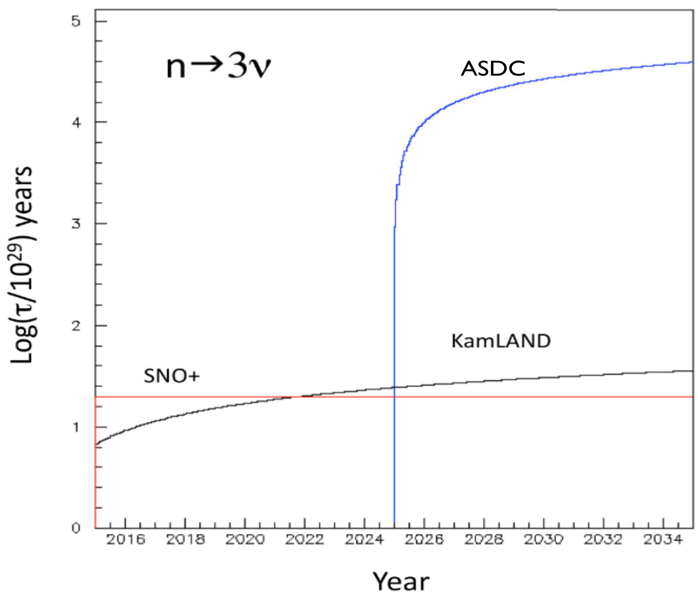
iv) Proton decay



Estimated sensitivity of a 100-kton ASDC experiment compared to Super-K. The improvement is due both to larger size and improved background reduction. If proposed long baseline detectors are built, Hyper-K would be better but LBNE worse for detecting this mode of proton decay. The upper ASDC curve assumes 90% background reduction due to neutron tagging, whereas the lower curve assumes no neutron tagging.



Estimated sensitivity of a 100-kton ASDC experiment compared to Super-K. The improvement is due to larger size, much improved efficiency, and improved background reduction. The upper ASDC curve assumes 90% background reduction due to neutron tagging, whereas the lower curve assumes no neutron tagging. LBNE efficiency and background numbers are from Bueno et al.

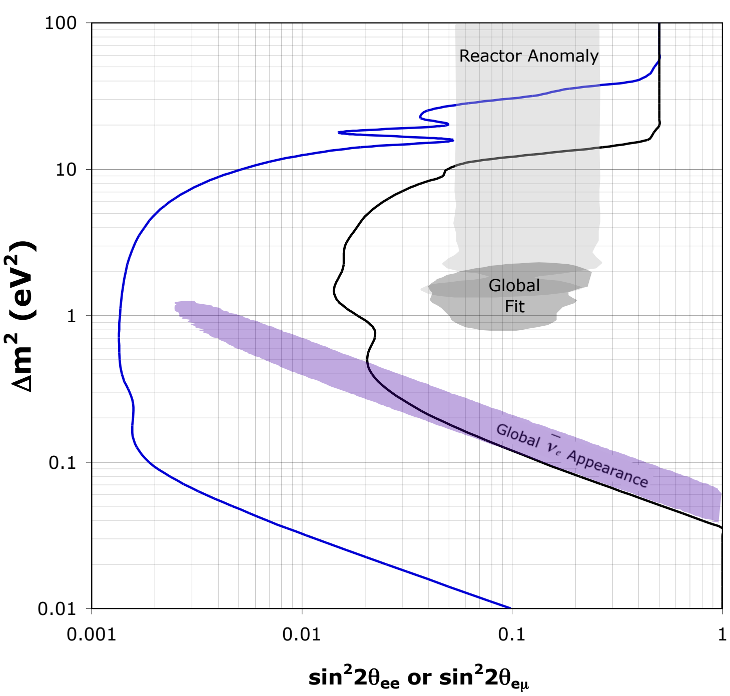


Estimated sensitivity of a 100-kton ASDC experiment compared to an extrapolated KamLAND sensitivity, plus the sensitivity expected from the water phase of SNO+. Sensitivity is clearly background limited, so background reduction by neutron tagging and directional reconstruction in an ASDC is significant.

a-c. See figures for predicted sensitivity.
d. Dominated by statistics.
e. All large-mass detectors e.g. ELBNF, SuperK, HyperK, SNO+, KamLAND
f. Different technologies are more sensitive to different modes of nucleon decay, as illustrated in the sensitivity figures.

11. Secondary Physics Goal
    a. Expected results/sensitivity
    b. List other experiments that have similar physics goals

i) Sterile neutrinos



The disappearance sensitivity with respect to the short baseline anomalies of a 20 kt (blue curve) and 1kt (black curve) highly-doped ASDC detector paired with the IsoDAR antineutrino source. Assuming CPT is a good symmetry, this program will decisively address all of present indications of sterile neutrinos. The shaded areas indicate the allowed regions for the RAA (gray), the global oscillation fit (dark gray), and the global appearance fit (purple).

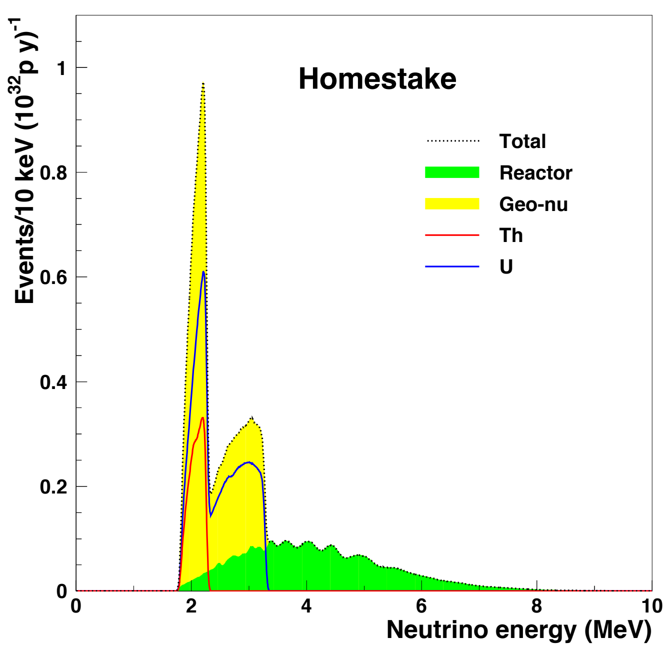
a. See figure for predicted sensitivity.
b. Many and varied! Including Prospect, NuLat, IsoDAR, CeSOX, Cr-51

ii) Supernova, DSNB

a. Expect 12,000 events in a 50kt volume from a supernova at 10kpc. High precision measurement due to strong n tag from low-threshold scintillation light + potential Gd loading. Allows:
   - Improved efficiency on other signals due to high-confidence IBD ID
   - Pointing accuracy doubled over equivalent WCD via ES events
   - Detection of mono-energetic gammas from NC
   - Detection of CC interactions
b. For a galactic supernova, many and varied, including - SuperK, HyperK, ELBNF, SNO+, HALO etc.
   For DSNB, only SK with Gd loading would be competitive, and ASDC would be deeper and probably larger than SK.

iii) Geo-neutrinos

a. Large statistics due to large (100kt) target mass. High confidence tag of IBD events, with good energy resolution. Low reactor background at the Homestake mine in SD.
b. Borexino, KamLAND, SNO+



12. Experimental requirements
    a. Provide requirements for each physics goal

i) Long-baseline neutrinos sensitivity studies assumed
- **250-kt-MW-years in an 80-GeV beam. Beam optimization studies will of course impact the sensitivity.**
- **40kt fiducial volume.**
- **3 + 3 years running**
- **Location at the Homestake mine in SD**

ii) Neutrinoless double beta decay sensitivity studies assumed
- **50kt total volume (30kt fiducial)**
- **0.5% loading of natural Te**
- **160 pe/MeV light collection**
- **10 years running**
- **Deep underground location to minimize cosmogenic background**

iii) Solar neutrinos sensitivity studies assumed
- **50kt total volume (30kt fiducial)**
- **100 pe/MeV light collection**
- **1% loading of 7Li by mass**
- **5 years running**
- **Deep underground location to minimize cosmogenic background**

iv) Proton decay sensitivity studies assumed
- **100kt fiducial volume**
- **Deep underground location to minimize cosmogenic background (n->3nu mode)**

v) Sterile neutrinos sensitivity studies assumed
- **20kt fiducial volume.**
- **IsoDAR capabilities including antineutrino production rate of 1.3×10^{23} in 4.5 years (see arXiv:1409.5864 for detailed table of performance parameters).**
- **5 years of running.**
- **Space to deploy IsoDAR in the ASDC cavern**

vi) Supernova and DSNB sensitivity studies assumed
- **50kt fiducial volume**
- **Ability to load Gd**

vii) Geo-neutrinos sensitivity studies assumed
- **No explicit assumptions**

13. Expected Experiment/Project time line
    a. Design and development
    b. Construction and Installation
    c. First data
    d. End of data taking
    e. Final results

We do not anticipate building this project over the 5-year timescale under consideration at the WINP meeting. Our request is for R&D support towards this long-term project.

14. Estimated cost range
    a. US contribution to the experiment/project
    b. International contribution to the experiment/project
    c. Operations cost

The total detector cost is estimated to be around $300M, critically dependent on photon detection technology and coverage. Since we are not requesting support for construction as part of the WINP process, we do not provide here a detailed cost breakdown for the full detector. Over the next 5 years we anticipate modest R&D costs towards developing this technology. Much of the technical R&D necessary for the ASDC would be accomplished by the joint DNN/HEP WATCHMAN project, and by the ANNIE experiment – should these both go ahead then the incremental R&D cost for ASDC would be minimal. We thus list scenarios with and without each of these projects: "Total cost" is the (annual) cost for ASDC alone, assuming neither WATCHMAN nor ANNIE. The subsequent columns list the much-reduced cost born by ASDC in the case of WATCHMAN and ANNIE going ahead.

Line item	**Time scale**	**Total cost per year**	**Cost /yr with WATCHMAN**	**Cost /yr with ANNIE**
WbLS target development and materials compatibility	**3-5 years**	**$240k**	**$80k**	
WbLS characterization and optimization	**3-5 years**	**$150k**	**$50k**	
WbLS recirculation development	**3 years**	**$100k**	**$0 (phase II)**	
Low-background, waterproofed 11" PMT development	**2 years**	**$65k**	**$0**	
LAPPD development and characterization	**1-2 years**	**$100k**	**$10k**	**$10k**
Fast readout development	**1-2 years**	**$100k**	**$10k**	**$10k**

15. The Future
    We are requesting support for R&D towards this long-range project, which would be a user of the anticipated LBNF.